

**Adult Steelhead Population Size and
Salmonid Migrants of the Keogh River
during the Spring, 1990**

by

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FISHERIES TECHNICAL CIRCULAR No. 89

1990



Province of British Columbia
Ministry of Environment

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**Fisheries Technical Circular No. 89
1990**

Canadian Cataloguing in Publication Data

Ward, B. R. (Bruce R.), 1952-

Adult steelhead population size and salmonid
migrants of the Keogh River during the spring 1990

(Fisheries technical circular, ISSN 0229-1150 ;
no. 89)

Issued by the Recreational Fisheries Branch.
Includes bibliographical references.
ISBN 0-7726-1224-2

1. Steelhead (Fish) - British Columbia - Keogh
River. 2. Steelhead (Fish) - Size. 3. Fish
populations - British Columbia - Keogh River.
4. Salmon - Migration. I. Burrows, J. A., 1966-
II. Quamme, D. L., 1966- . III. British
Columbia. Ministry of Environment. IV. British
Columbia. Recreational Fisheries Branch. V. Title.
VI. Series.

SH167.T86W272 1990 639.3'755 C91-092008-7

Ward, B.R., J.A. Burrows, and D.L. Quamme. 1990. Adult steelhead population size and salmonid migrants of the Keogh River during the spring, 1990. Prov. B.C. Fish. Tech. Circ. No. 89. 29 p.

ABSTRACT

Data obtained in 1990 from a fish counting fence installed on the Keogh River, a coastal stream located on northeastern Vancouver Island near Port Hardy, B.C., added to more than a decade of information collected on wild steelhead trout (*Oncorhynchus mykiss*). The total number of wild adults in 1990 was estimated to be 1,374; the sex ratio of which was 1:1.1, female to male. Mean lengths and weights were obtained for wild spawners (males 795.4 mm, 5.8 kg; females 764.9 mm, 4.9 kg), and mean lengths were obtained for wild kelts (males 764.1 mm, females 758.6 mm). Wild fish were estimated to comprise 72% and hatchery fish 28% of the total steelhead run on the Keogh River. The migration of wild adult steelhead was biased to the late-run component, which was relatively abundant, yet preliminary estimates of oceanic survival were low for smolts which contributed to these returns. Preliminary returns of pen-reared smolts released early in May 1988 were compared to returns of fish which were released at the peak of wild steelhead smolts. After two years at sea, the later release returned at a rate twice that of the early release.

All smolts were captured. Total captures of wild fish were low compared to averages in past years: steelhead smolts, 3,133 fish (mean length 166 mm, mean weight 40.8 g); steelhead parr, 757 (103 mm, 11.6 g); coho smolts, 57,238 (103 mm, 11.4 g); cutthroat trout, 205 (156 mm, 38.1 g); Dolly Varden adults, 721 (259 mm, 126.6 g); Dolly Varden smolts, 3,200 (145 mm, 29.7 g); Dolly Varden parr, 50 (110 mm, 11.1 g); and cottids, 1,388 (125 mm, 30.7 g). Peak migrations were May 7 (505 fish) and June 2 (362) for steelhead smolts; May 7 (76), May 8 (75) and June 12 (60) for steelhead parr; and May 7 (6,305) for coho smolts. From May 16 to June 13, a total of 1,423 steelhead smolts (45.4% of those captured) were manually tagged in the adipose fin with sequentially coded wire tags to examine the relationships of smolts' size, sex, migration time, and age and their subsequent survival and age-at-return. From May 1-31 a total of 22,715 coho smolts (39.7%) were coded-wire tagged, with tag numbers stratified into three time periods, as in 1988.

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INTRODUCTION

The Keogh River trapping facility has been a key site for continuous salmonid enumeration studies in British Columbia since 1975 (Ward and Slaney 1988, Ward and Wightman 1989, Irvine and Ward 1989). The primary objective of 1990 operations was to document marine survival of wild winter-run steelhead (*Oncorhynchus mykiss*). A secondary objective was to examine life history trends and relationships. This data series has been important to the understanding and management of British Columbia's steelhead trout. It provides an indication of stock status, serves to monitor the effects of environmental change, and provides basic data on possible functional relationships in steelhead life history. Thus, this research is guided by the main strategic objective of the Provincial Fisheries Program, i.e., conserving wild fish stocks.

Other anadromous research activities have been closely linked with this monitoring activity. Objectives in 1990 included the following research projects:

- documentation of the return to smolt production unaffected by enhanced nutrient conditions during rearing (Johnston et al. 1990),
- comparison of the adult returns of hatchery smolts which were released early in May versus releases coinciding with the peak timing of wild steelhead smolts,
- comparison of the oceanic survivals and age at return of wild versus hatchery steelhead,
- documentation of recurring migratory patterns of salmonid smolts,
- examination of post-spawning (riverine) and between spawning (marine) survival of steelhead kelts,
- continued evaluation of factors affecting the oceanic survival and age at return of wild steelhead,
- description of steelhead egg-to-smolt population dynamics and preliminary stock recruitment relationships.

New research in 1990 involved hand-injected coded-wire tagging in the adipose fin of roughly 40% of the steelhead smolts. This will facilitate analysis of the role of migration time, age, sex, and size of smolts in their subsequent survival and age at return. Co-operative research with the Department of Fisheries and Oceans continued on the assessment of the role of smolt migration timing by coded-wire tagging (cwt) of coho salmon smolts (*O. kisutch*). In addition, graduate student work commenced on examination of the causal factors in steelhead parr emigrations, coho smolt sub-

population dynamics, and functional relationships between nutrients, periphyton, and invertebrates. Data of this report will be useful in these ancillary projects.

In this data report, we summarize the 1990 fence operations, and the catches of steelhead trout adults and kelts (including the estimated population size), steelhead smolts and parr, coho smolts, Dolly Varden (*Salvelinus malma*) adults, smolts and parr, cutthroat trout (*O. clarki*) adults, smolts and parr, and sculpins (*Cottus* spp.). We report on fish numbers, sizes, migration timing, fence efficiency of capture, and provide a preliminary description and evaluation of a new fish marking technique (adipose cwt). This paper also serves as a description of methods for reference in future operation and reporting of fisheries research conducted at the Keogh River.

METHODS

TRAP DESCRIPTION AND OPERATION

The Keogh River and the site of the fish counting fence near the mouth (Fig. 1) were described elsewhere (Mottram 1977, Ward and Slaney 1988, Irvine and Ward 1989).

In 1990, the adult upstream and downstream traps were operational on February 23 and April 5, respectively. Kelt and the main smolt traps were installed by March 6. Ancillary hanging inclined plane traps (also called Wolfe or gulper traps) were in place on April 5 and sealed by April 10. A diver with snorkel inspected the entire fence underwater to check and eliminate holes through which juvenile fish could escape. Underwater inspections were continued at weekly intervals throughout the smolt enumeration and tagging period of early April to mid-June. Stop-log barriers below the main smolt trap were adjusted according to river flows and to ensure optimum fish passage into upstream and downstream traps. Early in the season, flow was directed through the upstream traps. Once the immigration of adults upstream subsided (May), more flow was then directed through the downstream traps to ensure efficient capture.

Gulpers were operated during rain-induced freshet events which occurred May 1-2 (requiring 6 gulpers to be used), May 6-8 (8 gulpers), and June 10-12 (1-2 gulpers). Fish screens were cleaned daily, or more frequently during higher flows.

FENCE EFFICIENCY TESTS

Three tests were carried out using coho smolts to assess the trap's efficiency at capturing smolts. In the first two tests, from April 27 to May 7, 500 fish > 120 mm and 500 fish < 120 mm

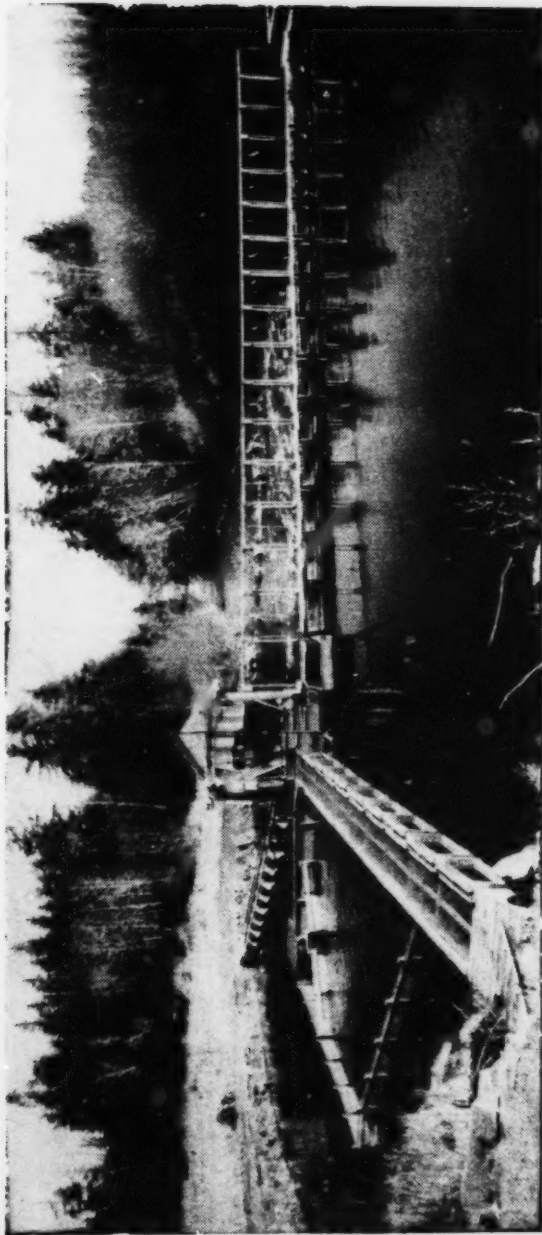


Figure 1. The fish trapping facility on the Keogh River, facing downstream. Capture of fish migrating upstream occurs in boxes on either side of the main fence. Gulper traps hang from the main fence. The smolt and kelt collection area is to the left. The stop-log fence downstream of the smolt collection area controls water velocity over the horizontally screened area upstream.

were marked with upper and lower caudal fin clips, respectively. Fish were not anaesthetized and were released immediately 30 m upstream of the fence. Recoveries were tabulated, by mark, as recaptures at the fence until June 13. From May 16 to June 3, 225 coho smolts > 120 mm were marked with lower caudal fin clips and similarly released and recaptured, as a third efficiency test. Also, tests for mark detection were possible during 12 separate occasions in May, as the coho smolts were examined for marks during enumeration and a second time during coded-wire tagging, when missed marks were recorded.

ADULT SAMPLING

Adults and kelts were sexed by external features and checked for various marks that indicated their origin (hatchery or wild). Adult fork lengths were measured, scale samples removed, and weights of 20% (every 5th fish) of the population were taken. Kelt fork lengths were measured and scale samples were taken from those fish previously unsampled. Body colour ("brightness") was represented as a relative number from 1 (low coloration) to 4 (high coloration). Ripeness was also assessed on a relative scale from 1 (not ready to spawn) to 4 (ready to spawn) and 5 (spawned kelt), and the general condition of each fish was noted, including number of scars or wounds (data on file). Upstream migrants were marked by punching a small hole in the left operculum (Ward and Slaney 1988, 1990).

Adult and kelt traps were checked and emptied at least twice daily. Each fish was removed from the trap with a dipnet and placed in a sling to be carefully restrained during sampling. After data collection, the fish was released upstream (adult) or downstream (kelt) of the fence. On average, ten adults were processed in approx. 30 minutes. Anaesthetic was not used in the sampling of adults or kelts. Ovidyne was used daily to disinfect processing equipment.

The fence was not operated during the early-run portion of the adult steelhead immigration, from December to February. Although an earlier comparison of the survival of early- versus late-run fish showed no difference, there may be annual variability. Intensive angling by staff and volunteers provided information on the relative run strength of this portion of the population, and provided an opportunity to mark fish. Numbered Floy tags (Floy Manufacturing, Seattle, U.S.A.) were inserted in front of the dorsal fin, anchored in the base of the dorsal rays, of ten of the angled steelhead. Over several years of tagging, we hope to assess the comparative in-river survival of early and late-run adults. Fifteen fish were marked with a right operculum punch in January. Recaptured kelts were sampled as described above, and the tag numbers and marks recorded.

As described in Ward and Slaney (1988, 1990) and Slaney et al. (1990), the total numbers of adult males and females were estimated separately by mark and recapture using the adjusted Petersen estimate (Ricker 1975) by marking upstream migrant adults and capturing kelts during their downstream migration. Kelts, captured as they emigrated, were examined for operculum holes. The estimated population size was calculated as:

$$N = (M+1)(C+1)/(R+1)$$

where N = Petersen population estimate
 M = number of marked adults
 C = number of captured kelts
 R = number of recaptured kelts

Confidence limits (C.L.) on the male and female population estimates were calculated based on the Poisson frequency distribution where R is substituted for x in Appendix II of Ricker (1975). The C.L. for joint estimates of males and females were approximated based on the principal of additivity of variance (J. Berkowitz, U.B.C., pers. comm.):

$$\begin{aligned} \text{and} \quad -95\% \text{ C.L.} &= N - [(N_m - L_m)^2 + (N_f - L_f)^2]^{-2} \\ +95\% \text{ C.L.} &= N + [(U_m - N_m)^2 + (U_f - N_f)^2]^{-2} \end{aligned}$$

where N_m = male N
 N_f = female N
 L_m = lower C.L. on the female N
 L_f = lower C.L. on the male N
 U_m = upper C.L. on male N
 U_f = upper C.L. on female N

SMOLT SAMPLING AND TAGGING

Fish captured in the smolt trap were processed daily, following the sampling of adults and kelts. Two 1,000 l tanks, continuously supplied with fresh water by a submersible pump, were used to hold downstream migrants. All fish were counted and we attempted to keep the fraction of each species randomly sampled for lengths and weights constant throughout the trapping period, with the exceptions of steelhead smolts and coho smolts. Sampling intensity increased for steelhead smolts upon commencement of coded-wire tagging. For coho smolts, the lesser of the whole day's catch or 25 fish chosen at random were sampled for lengths, weights, and scales. Scale samples from above the lateral line just behind the dorsal fin were taken from steelhead smolts in a sampling regime that was stratified according to fish size and migration time (Ward et al. 1989). With commencement of coded-wire tagging, lengths, weights, and scales were sampled from all tagged steelhead smolts.

Fork lengths (mm) were taken from all fish in the subsample every day, and weights (to nearest 0.1 g) from these fish were taken twice per week using an Ohaus electronic scale. Fish sampled for weights and also fish which were coded-wire tagged were anaesthetized in a 0.5% solution of 2-phenoxy ethanol, and allowed to recover before release. Anaesthetized and non-anaesthetized steelhead smolts were held in fresh and salt water tanks (2 replicates of each) for 24, 48, and 72 hrs to test possible effects of the handling procedure. These fish were also used to test coded-wire tag retention in the adipose fin.

Sequentially coded binary wire tags (Northwest Marine Technology, Inc., Olympia, Washington) were inserted in the adipose fin of steelhead smolts. Tags are 1.1 mm in length and have a six-row data format, the first being the agency code (2). The first two formats are read like the standard cwt. There are 11,840 possible sequence numbers which can be represented by the two seven-bit fields (data 3 and 4). Sequentially marked wire is read and the code must be found in a table to determine the sequence number.

Manual tagging of steelhead smolts in the adipose fin with sequentially coded wire tags was conducted from May 16 to May 24, when 42.2% of the smolts were tagged, and May 24 to June 13, when 89.2% of the smolts were tagged. Tags were loaded by hand from a silicone strip into an hypodermic syringe injector, and inserted into the adipose fin from the fin's origin towards its trailing edge (i.e., the needle was tilted up from the body of the fish). This procedure usually implanted the cwt at or near the centre of the fin, where it was clearly visible. Times for cwt loading as well as loading, tagging and sampling were recorded for teams of one, two, and three people. Seven 24 hr and one 72 hr tag retention tests were performed.

The manufacturer recommended saving alternate tags to ensure that fish were individually marked. This advice was followed with the exception of the first three silicon strips (approx 300 tags). From the first strip, one CWT was saved for every four fish tagged, and from the second and third strips, two CWTs were saved for every fish tagged. Saving alternate tags in the strips should allow identification of individual fish upon recovery of the cwt from the adipose fin of an adult return (J. Kallshian, pers. comm., Northwest Marine Technology, Inc., Olympia, Wash.).

Examination of the role of migration time in the subsequent migration and survival estimates of coho salmon smolts continued at the Keogh River in 1990, as done in 1988 (data on file: J.R. Irvine and R. Bailey, Department of Fisheries and Oceans). Coho smolts were coded-wire nose-tagged by machine from May 1 to May 31 using a Mark IV tagger (Northwest Marine Technology, Inc.) as described in Irvine and Ward (1989). During this period 39.7% of

the coho smolt emigrants were tagged and released. Three different tag codes were used for each of the following periods: May 1-May 12, May 13-May 19, and May 20-May 31. For each tagging period, a 24-hr tag retention test was performed.

RESULTS AND DISCUSSION

ADULT STEELHEAD

Numbers of Wild and Hatchery Steelhead

The estimate of total (wild plus hatchery) adult steelhead returning to the Keogh River in 1990 was 1,915 fish (Table 1). The recapture rate of male kelts was 9% of the fish marked as upstream migrants, whereas the rate of recapture of females was about 5 times higher, or 47%. Thus, population estimates were stratified by sex, as described in Ward and Slaney (1988). The number of adults captured and marked was 725 (498 wild, 227 hatchery), and the number of kelts captured and examined for marks was 573 (397 wild and 176 hatchery fish). Fifty-three percent of the estimated population was handled either as an upstream migrant adult or an unmarked downstream migrant kelt (Table 1).

Sex ratios differed for wild and hatchery returns of steelhead trout. Hatchery adults were predominantly males (61%) whereas the sex ratio of wild fish was 1.1:1. However, we have more confidence in the estimate of female numbers than in male numbers, due to the typically low recapture rate of males (Ward and Slaney 1988), and this is reflected in the broader confidence limits on the male population estimates (Table 1).

Fish returning with a clipped adipose fin could represent strays from smolt releases in neighbouring streams (Quatse and Cluxewe Rivers). A straying rate of approx 30% was expected based on previous experience (Ward and Slaney 1990) and results elsewhere on Vancouver Island (Lurette and Hooton 1988). On this basis, about 400 adults were expected and we estimated that 474 returned (Table 1). Variation in age at return could account for part of this difference. A portion of adipose-clipped fish and all the fish with left maxillary clips could represent repeat spawning hatchery fish from previous smolt releases in the Keogh River (e.g., Slaney et al. 1990), and scale analysis will assist with this interpretation. We recommend different marks (e.g., pelvic fin clips in addition to the adipose) be assigned to smolts released in at least one of the two neighbouring rivers since we have the unique opportunity to assess the relative contributions from each release site. This may differ due to the migration path of the adults through Queen Charlotte Strait. Information on relative straying rates could have important implications to stock management.

Table 1. Population estimates of steelhead trout adults of the Keogh River, 1990.

MALES								
	RO Marks	LO Marks	Mortalities	New	Recaptures	N	-95%CL	+95%CL
Wild	7	148	0	49	14	666	408	1148
Adipose	1	62	0	14	3	288	118	720
LM	0	2	0	0	0	3	1	3
LMA	0	5	0	3	2	12	4	30
RMA	0	12	0	8	4	34	15	85
Total	8	229	0	74	23	972	659	1495

FEMALES								
	RO Marks	LO Marks	Mortalities	New	Recaptures	N	-95%CL	+95%CL
Wild	5	338	1	172	162	708	608	825
Adipose	1	133	1	35	94	186	152	227
LM	0	2	0	2	2	5	2	13
LMA	0	4	0	1	2	7	2	17
RMA	1	4	0	1	5	7	3	16
Total	7	481	2	211	265	879	780	990

MALES AND FEMALES			
	N	-95%CL	+95%CL
Wild	1374	1097	1870
Adipose	474	300	908
LM	8	4	16
LMA	19	10	39
RMA	41	22	92
TOTAL	1915	1587	2450

Returns of the LMA (left maxillary and adipose fin clipped) and RMA (right maxillary and adipose) fish were low (Table 1). These fish were released as smolts at different times in 1988, after rearing one year at O'Connor Lake net pens. The LMA group (2,593 fish) was released as smolts on May 7, 1988, (mean length 191 mm, mean weight 72.5 g), whereas the RMA group (2,860 fish) was released during the peak of the wild steelhead smolt migration, on May 26, 1988 (mean length 205 mm, mean weight 81.3 g). The estimated returns after two years at sea (Table 1) suggest higher success with a release strategy that corresponds with the peak in migration of wild smolts. Actual numbers of RMA (26) recovered (marked adults and unmarked kelts) were double that for LMA (13). However, population estimates are based on low numbers of recaptures, and fish returning after three years at sea must be included to complete this analysis. This release schedule was repeated in 1990, with a release of 1,986 fish on May 5 (168 mm, 50.3 g), and a second release of 4,019 fish on May 24 (170 mm, 50.5 g), also liberated downstream of the fish fence. As suggested from the population estimates and the counts of new fish of ocean-age 2 (Table 1), a doubling of returns may be possible if the release schedules for hatchery fish are adjusted to match wild fish behaviour. Further research is required.

Migration Timing

A significant feature of the 1990 steelhead run was the poor relative return of early-run (Dec. to Feb. incl.) fish. This was apparent from the mark-recapture data as well as from intensive efforts by several experienced anglers during January and February.

The late-run fish were captured at the fence. The upstream migration of spawning adult steelhead and the downstream migration of steelhead kelts was monitored starting February 26 with the installation of the fish counting fence, and continued uninterrupted through to the completion of the migration on June 3, when the last kelt was sampled. Eighty-seven percent of the adults which passed through the trap were released upstream of the fence during the weeks of March 12 to April 22 (Fig. 2). Ninety percent of the kelts processed were released downstream of the fence during the week of April 16 to May 6 (Fig. 3). The run-timing curve for 1990 was thus compressed relative to other years, and the low abundance of unmarked (new) kelts (15%) further suggests a poor return of the early-run component.

If the migration behaviour of the steelhead population of the Keogh River was similar to other, at least local, populations, then it is possible that the Steelhead Harvest Analysis (e.g., Billings 1988) will not reflect true population levels in 1990. Several reasons may account for this. First, anglers were possibly unable to capitalize on this brief immigration period. Second, steelhead

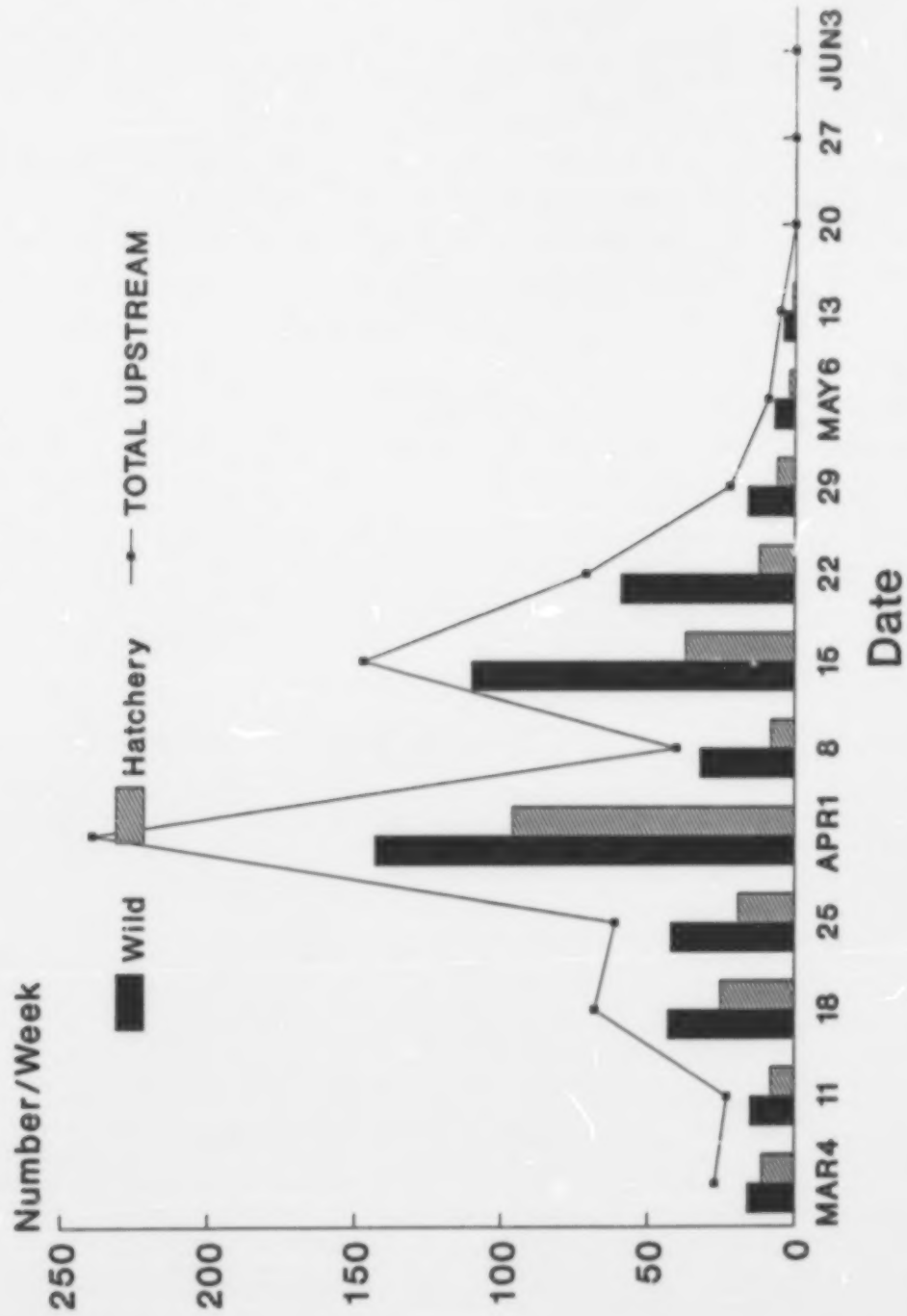


Figure 2. The migration timing of wild and hatchery steelhead adults migrating upstream through the Keogh River fish fence, 1990.

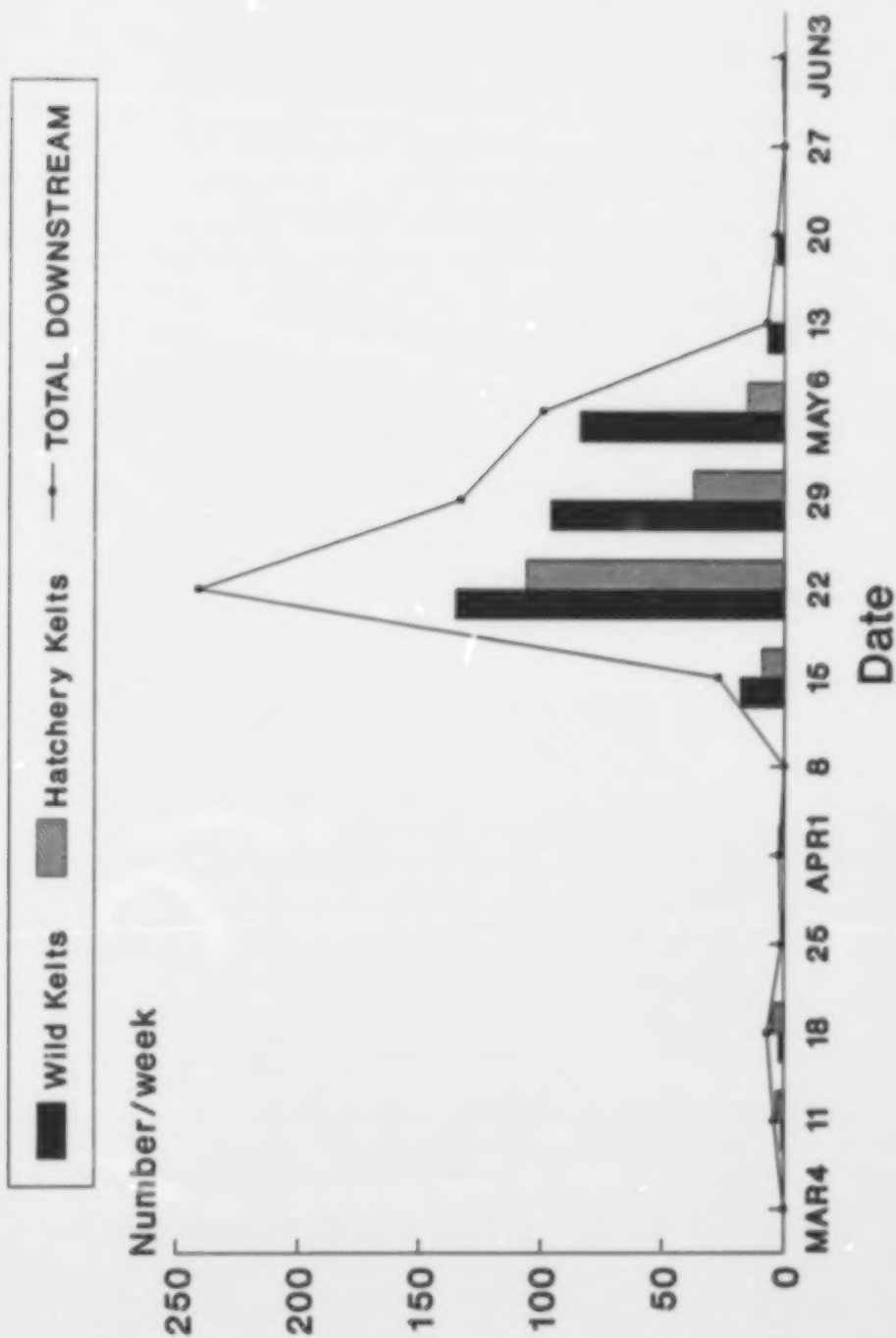


Figure 3. The migration timing of wild and hatchery steelhead kelts passing downstream at the Keogh River, 1990.

anglers often do not fish as intensively during the first weeks of April due to the presence of kelts, nor has this period been included in the questionnaire analysis for the given year. Furthermore, low catch per unit effort in the early-run period likely reduces willingness to participate in the late-run period. In the past, Keogh run strength and harvest analysis results showed parallel trends (Ward and Wightman 1989). In years such as this one, managers should depend on the more reliable fence counts and population estimates to assess stock status, rather than angler surveys which may be biased by run-timing differences between years.

The within-season hatchery and wild migrations closely paralleled each other, as found earlier with survival rates and age-at-return (Ward and Slaney 1990). However, weekly totals show that hatchery fish may have had an earlier migration timing. Seventy percent of the hatchery fish were enumerated by April 1, whereas only 53% of the wild adults were counted by this date (Fig. 2). Similarly, 71% of the enumerated hatchery kelts passed downstream by April 20, whereas only 45% of the wild kelt run was completed by this date (Fig. 3). This further suggests the early run of wild steelhead was relatively weak compared to the late run and compared to the hatchery returns.

Only two of the fifteen tagged early-run fish were recaptured at the fence as kelts (one wild male and one hatchery male). The wild fish spent 54 days in the river before exiting, whereas the hatchery fish was only 19 days between captures. Sample size was insufficient to provide a comparison of in-river survival of adults from the early versus the late run. The recovery of late-run fish as kelts was approx. 36%.

This early-run tagging should be repeated each year to gain knowledge of the functional relationships between fish size, sex, length of time in the river, and mortality. An estimate of this mortality rate is important for determination of the accuracy of our population estimates. A higher mortality of early-run fish would mean that the true N is higher than we estimate. A correction factor for angling mortality would normally be required in these calculations. Angling mortality was estimated in an earlier study on the Keogh River to be 5% or less (Hooton 1987). However, numbers tagged were too low for angling mortality effects to have a serious impact on the estimates. The primary purpose of the marking study is to ensure some of the early-run adults are sampled for size and age, as well as marking.

A relatively weak early run of adults may have been caused by less favourable oceanic conditions for those fish (earlier migration suggests different ocean areas are utilized compared to their later cohorts) or a failure of the contributing portion of the smolt run during stream rearing. Since it appears that the progeny of early-run spawners rear mainly in the upper reaches of

the watershed (Ward and Slaney 1979), low flow and drought conditions might impact this portion of the population during parr stages to a greater degree than their late-run (lower river) cohorts. Alternatively, the early-run progeny may have been more impacted during the egg-to-fry stage because the adults spawn earlier.

Migration patterns assessed by fish capture may have depended largely on stream flow conditions during both adult entry and kelt exit. Gauge height recordings (data on file) during the field season strongly suggest this, and fish were more likely to be caught during freshet events.

Adult Lengths and Weights

Lengths of adult and kelt steelhead were highly variable, depending on the type (wild or hatchery) and sex (Table 2). Differences in adult size were associated with year of smolting, age and sex (Ward and Slaney 1988). The data was not stratified by freshwater and saltwater age. This could account for the large standard deviations and ranges shown in the 1990 data.

Table 2. Mean size of steelhead adults and kelts of the Keogh River during 1990.

Type	Sex	Adults					Weight (Kg)			
		Length (mm)								
		Mean	Minimum	Maximum	S.D.	n	Mean	Minimum	Maximum	n
Wild	male	795	600	950	80	148	5.8	3.0	8.6	26
	female	765	485	930	57	339	4.9	1.9	8.2	75
Hatchery Adipose	male	802	600	930	66	62	5.1	3.0	8.0	14
	female	759	540	840	63	134	5.1	3.0	7.4	26
Hatchery Other	male	672	605	875	76	19	3.0	3.2	3.6	3
	female	651	585	780	59	10	3.2	3.0	3.3	2
Kelts										
Wild	male	764	480	895	89	64				
	female	759	560	850	49	284				
Hatchery Adipose	male	773	605	910	91	17				
	female	764	600	855	42	129				
Hatchery Other	male	631	540	680	34	190				
	female	666	590	790	74	13				

SMOLT ENUMERATION

Fence Efficiency Tests

The trapping efficiency of the fence was tested three times. Recapture of fish was highest (84.0%) for coho smolts > 120 mm, which were marked and released upstream of the trap in late April and early May. For coho < 120 mm, released upstream of the fence during the same period, recoveries were lower (79.6%), and recoveries were lowest (39.6%) for coho > 120 mm released in late May for a third efficiency test. This was consistent with past practise and produced similar results.

We suspect that an inadequately sealed fence was not responsible for these low recovery rates (regular inspections by divers using snorkels revealed no holes). Rather, we suggest several other possible causes for the poor recoveries. Some proportion of the marked and released fish were not expected to return to the fence due to mortality from handling or predation after release. In the past, this was assumed to be approx. 5%. Another proportion may not have been recaptured due to failure to migrate, as defined by Slaney and Harrower (1980) and discussed in Ward and Slaney (1988). The latter, in particular, was suspected as a cause for the very low recovery rate of the third test, since several marked coho were seined above the fence at the end of the migration period. We typically seine above the fence at the end of the kelt migration period to capture remaining kelts and assist with their downstream migration at the low flow levels typical of that time, and in past years, we consistently captured residual coho with fin clips.

A significant error in detection of marked coho during enumeration was confirmed to have biased recovery rates downward from the true value. Undetected marks would have simply been enumerated as new fish, and this was evident from second counts done during tagging. On 12 separate occasions in May, upper caudal clips were checked a second time. The examiner found that 35 out of the 188 fish clipped (18.6%) were incorrectly classified as new, unmarked, fish. On 9 days in May, when lower caudal clips (on fish < 120 mm) were checked a second time, 30 out of 99 fish with this fin clip (30.3%) were missed in the first count.

Applying the detection rate of the upper caudal fin clip to the rest of the recapture period, a potential 53 clipped fish could have been missed. This would bring the fence efficiency estimate from 84% to 94.6%. Applying the detection rate for the lower caudal (< 120 mm) clip to the rest of the recapture period, a potential 173 clipped fish could have been missed, raising the fence efficiency estimate from 79.6% to 114.2%.

It is therefore probable that the fence was 100% efficient. Considering the regular checks for potential leaks (none were found) and the stable flow regime during the migration in 1990, the complete capture of fish was likely. High flow freshets were not common, and overflow traps (gulpers) were required only on three occasions, for short periods only, when few of the available traps were utilized. Steelhead smolts, larger than coho smolts, were even less likely to escape enumeration. Thus, no expansion factor was applied.

Steelhead Smolts and Parr

The steelhead smolt migration began April 18, and smolts were captured until June 13. Peak migration occurred May 7, when 505 smolts were captured. A second, smaller peak of 362 smolts occurred June 2 (Fig. 4). The first peak was three weeks earlier than last year (Galesloot, 1989) and one week earlier than in 1988 (Wilcox, 1989). The smolt migration in 1990 appeared to be associated with higher flows, compared to other years. Total catch in 1990 was 3,133 smolts, which was lower than the mean of 5543 smolts for 1977-1983 (Ward and Slaney, 1988). This relatively low yield could result in low levels of returning adults assuming average oceanic survivals (Ward 1988, 1989).

Mean length for 1990 steelhead smolts was 166 mm; mean weight was 40.8 g (Table 3). These were 4% and 17% less, respectively, than the average of means for 1977-1983. Thus, subsequent oceanic survival is expected to be low (Ward and Slaney 1988). However, smolt measurements were slightly biased to the latter part of the run, when tagging began and sampling intensity increased. There is a need to stratify these measurements according to numbers migrating and numbers sampled, then forecast returns based on smolt length intervals, as in the past (Ward 1988, 1989).

The length-frequency histogram of steelhead smolts indicates only one peak, at the 156-160 mm size range (Fig. 5). Scale analysis using the method described in Ward et al. (1989), will subsequently provide the age structure of 1990 steelhead smolts.

Steelhead parr began emigrating two weeks earlier than steelhead smolts, on April 5. Peak migration occurred May 7 and May 8 when 76 and 75 parr respectively were captured. A second peak occurred June 12, when 60 parr were captured (Fig. 4). The total catch for 1990 was 757 parr, comprising 19.5% of the total juvenile steelhead migration. Mean length and weight for steelhead parr was 103 mm and 11.6 g, respectively (Table 3). Parr were sampled intensively (88% for lengths, 84% for weights) throughout their migration which ended June 17. The length-frequency distribution of steelhead parr showed a peak in size at the 96-100 mm size range (data on file).

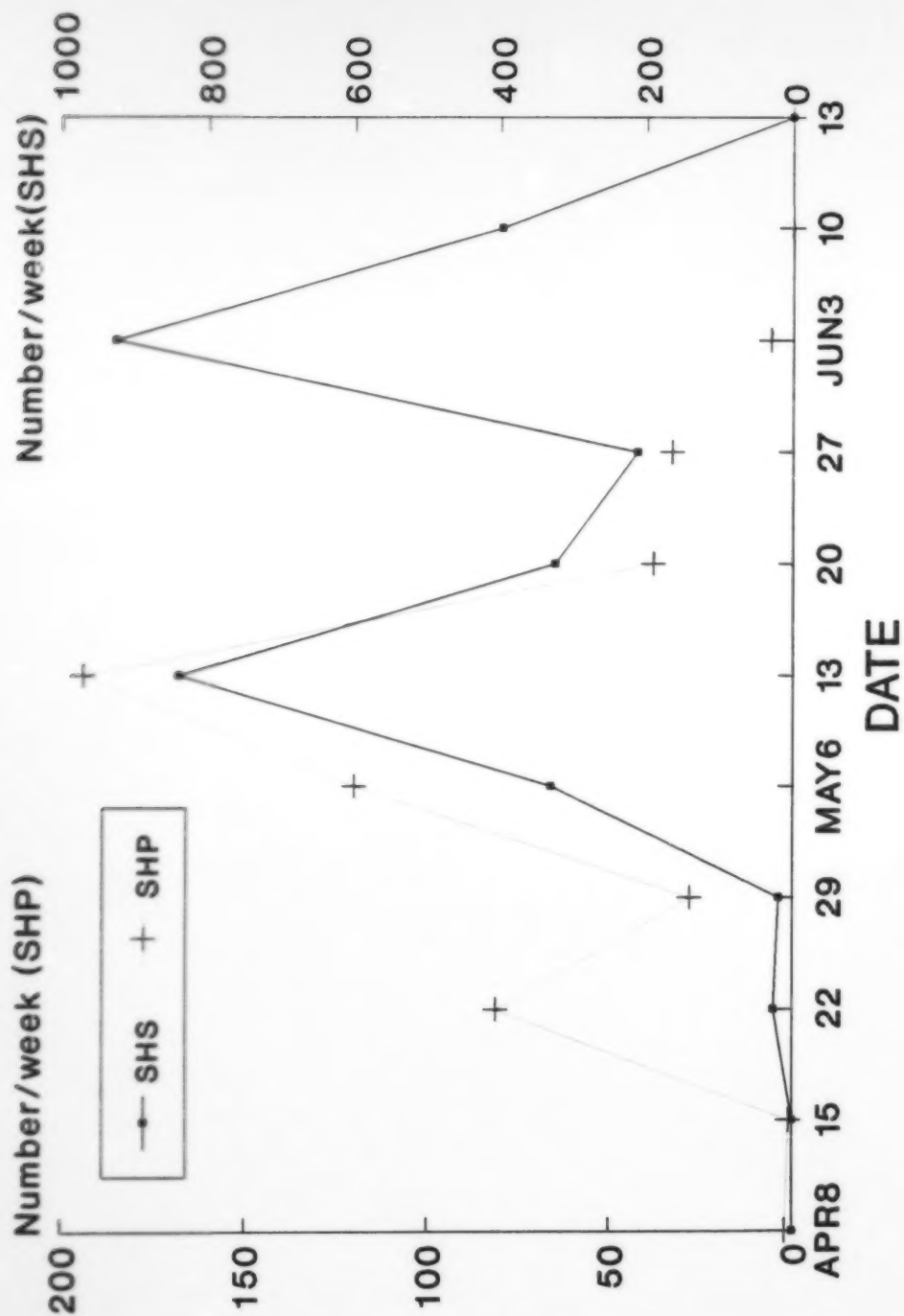
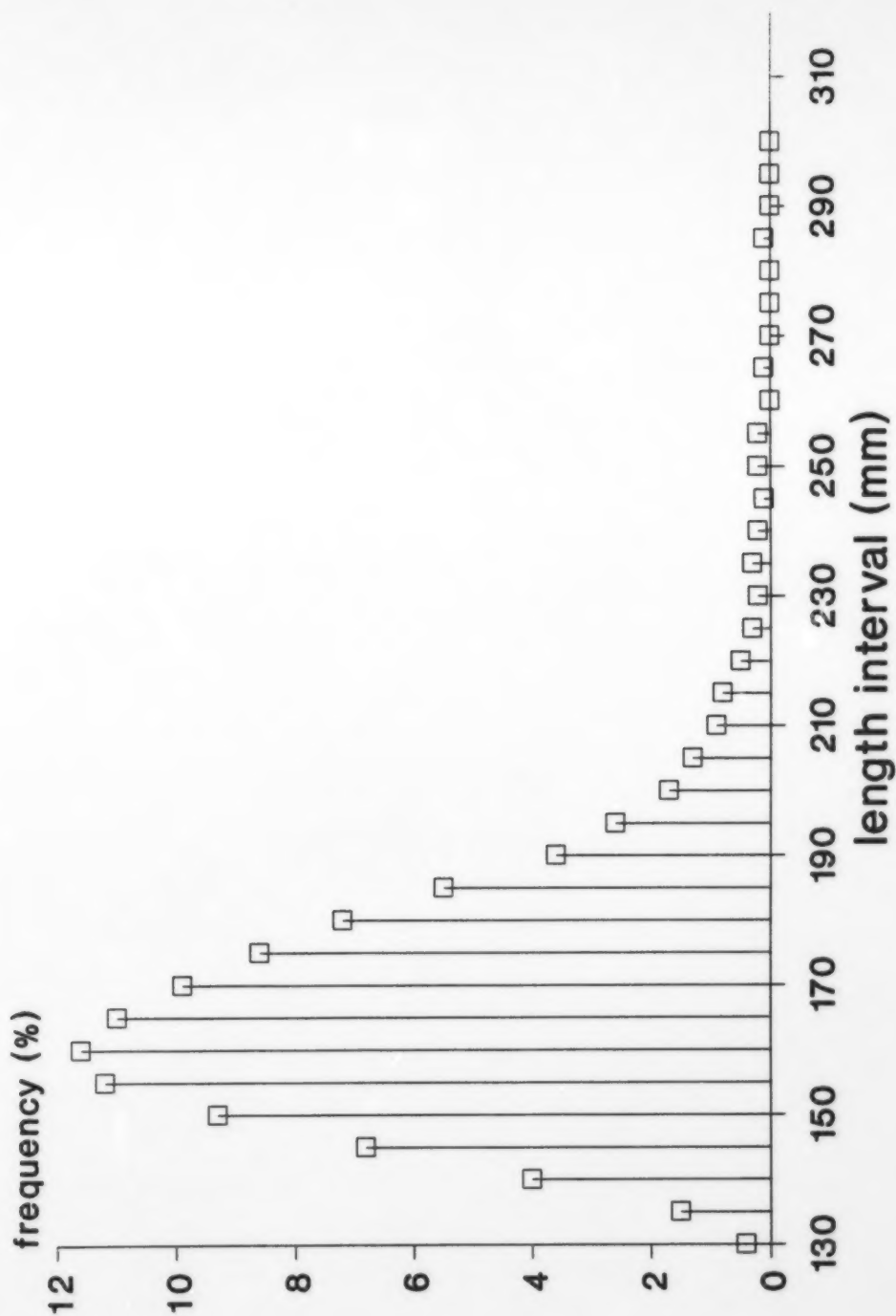


Figure 4. The timing of the steelhead smolt and parr emigration from the Keogh River, 1990.



$n = 1,759$

Figure 5. Length frequency distribution of steelhead smolts migrating in 1990 from the Keogh River.

Coho Smolts

The coho smolt migration peaked May 7 when 6,305 fish were captured in the smolt trap (Fig. 6). The date of the 1990 peak is similar to other years (Galesloot 1989, Wilcox 1989, Irvine and Ward 1989). The total coho smolt catch for 1990 was 57,238, which was lower than the historic average of 71,000 (Irvine and Ward 1989), but not the lowest on record (55,250 in 1982). Mean length and weight of coho smolts was 103 mm and 11.4 g, respectively (Table 3), which was similar to other years.

The large (> 200 mm) coho smolts (Fig. 7) enumerated in the 1990 migration likely originated from either Keogh Lake or O'Connor Lake where net pens were used to rear salmonids. These fish were either wild fish that fed and grew rapidly near the pens or unmarked fish which escaped from the pens. No coho smolts attained the size of these fish in past years (Wilcox 1989, Galesloot 1989, Irvine and Ward 1989). Sampling with gill nets near the net pen facilities later in the summer confirmed the presence of exceptionally large coho rearing nearby (data on file). We recommend careful monitoring of the ecological effects of fish culture in net-pens.

Table 3. Mean lengths (mm) and weights (g) of all species caught during the spring 1990 downstream migration at the Keogh River. (S.D. = standard deviation, n= sample size).

Species	Mean Length	S.D.	Range min-max	n	Mean Weight	S.D.	Range min-max	n
Steelhead								
Smolts	166	20.5	121-373	1761	40.8	20.0	16.6-260.6	862
Parr	103	18.1	56-182	665	11.6	6.4	1.7-53.8	636
Coho								
Smolts	103	20.7	69-327	1418	11.4	14.0	3.5-333.3	1298
Cuttthroat								
Adults	172	35.2	128-329	42	53.4	42.7	16.8-254.9	40
Smolts	160	20.5	121-214	116	38.6	16.4	15.2-87.3	112
Parr	127	22.5	83-174	37	20.6	10.7	6.1-47.1	37
Dolly Varden								
Adults	259	49.9	202-409	139	126.6	83.6	17.4-343.4	32
Smolts	145	17.2	62-237	640	29.7	18.9	11.9-24.2	222
Parr	110	11.7	88-125	9	11.1	4.0	6.4-16.5	5
Cottids	125	19.2	58-191	113	30.7	14.2	14.9-63.3	24

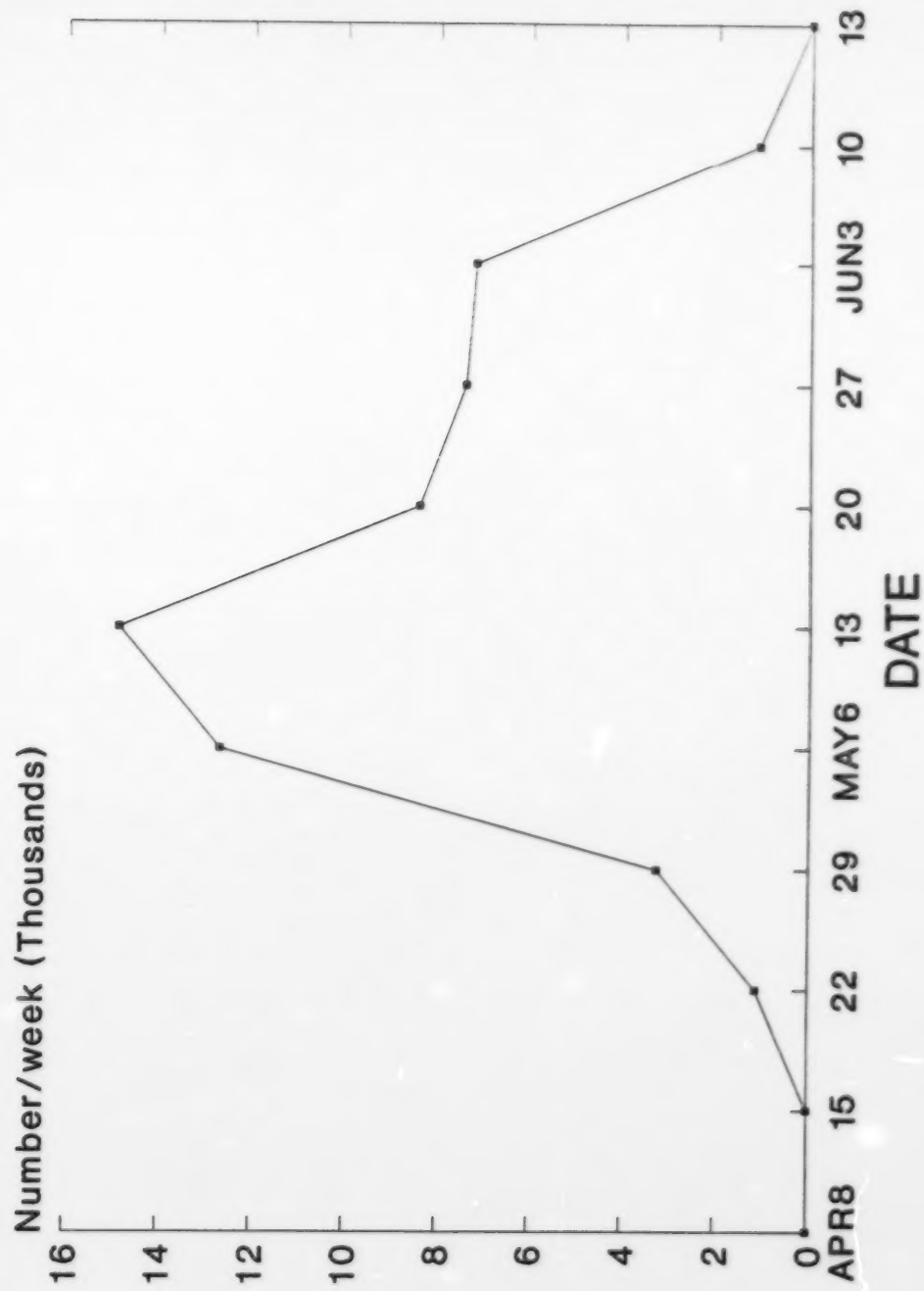
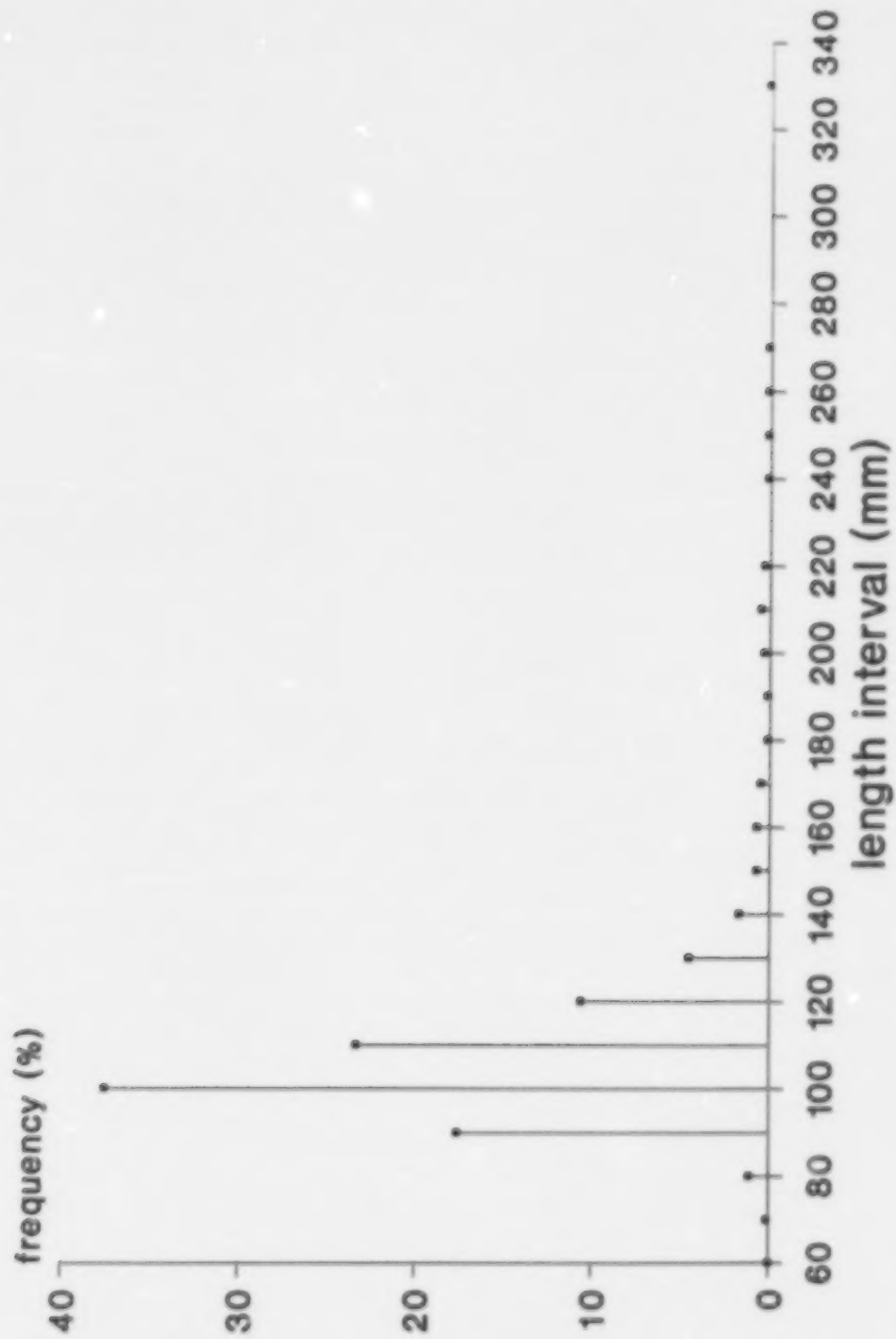


Figure 6. Migration pattern of coho salmon smolts.



n = 1,418

Figure 7. Length frequency distribution of coho salmon smolts, 1990.

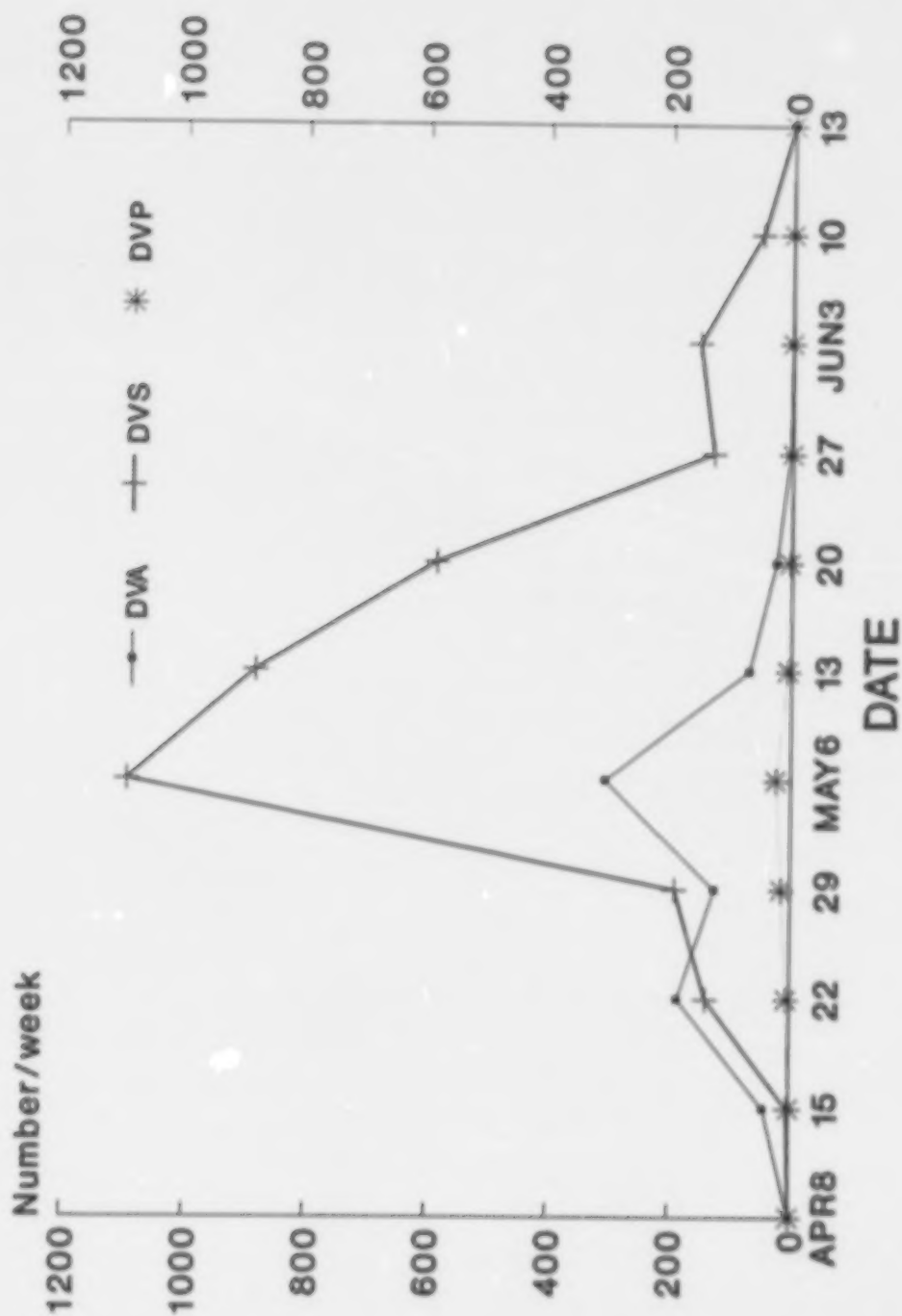


Figure 8. Migration pattern of Dolly Varden adults, smolts, and parr from the Keogh River in 1990.

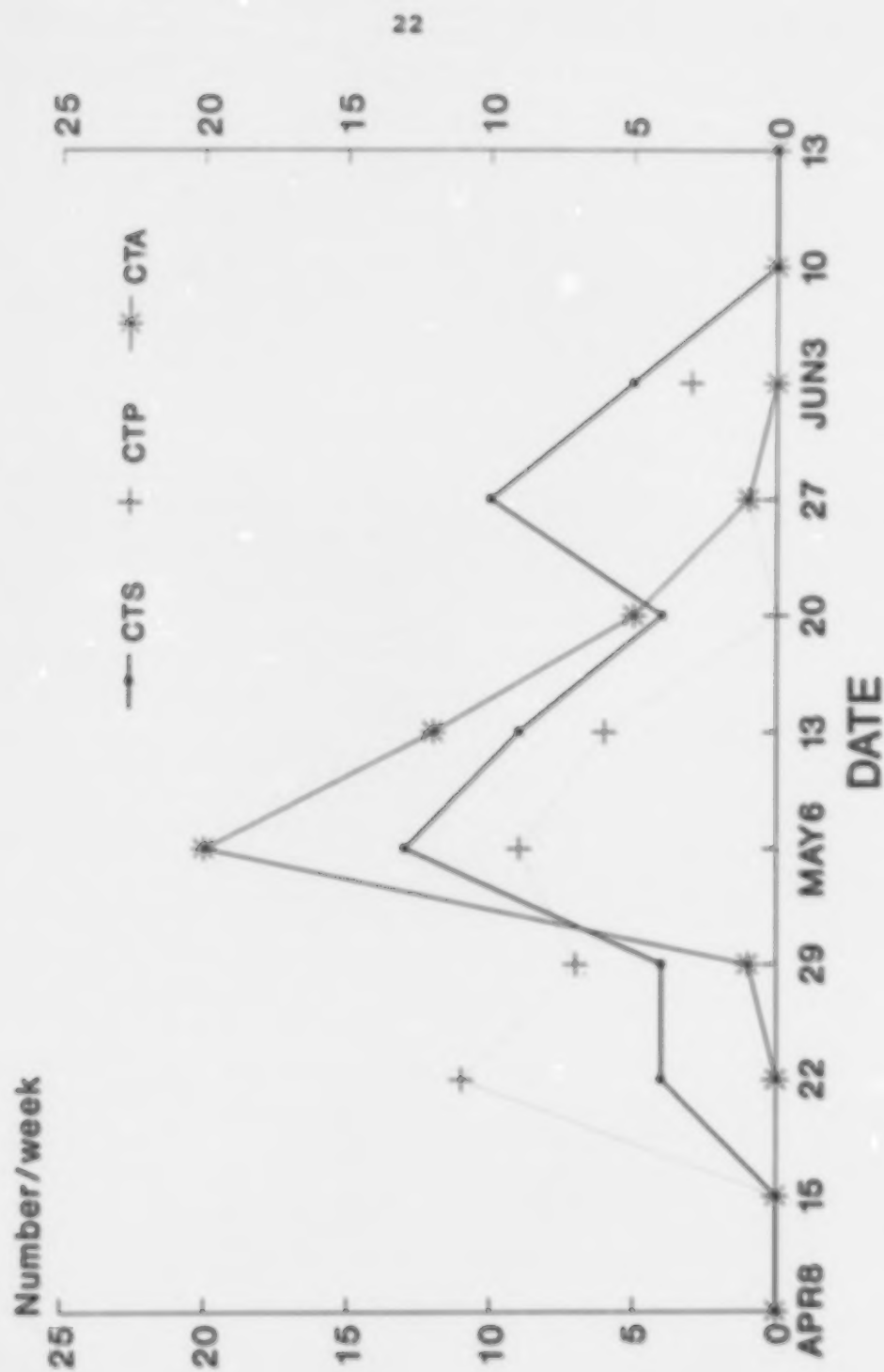


Figure 9. Migration pattern of Cutthroat trout from the Keogh River in the spring of 1990.

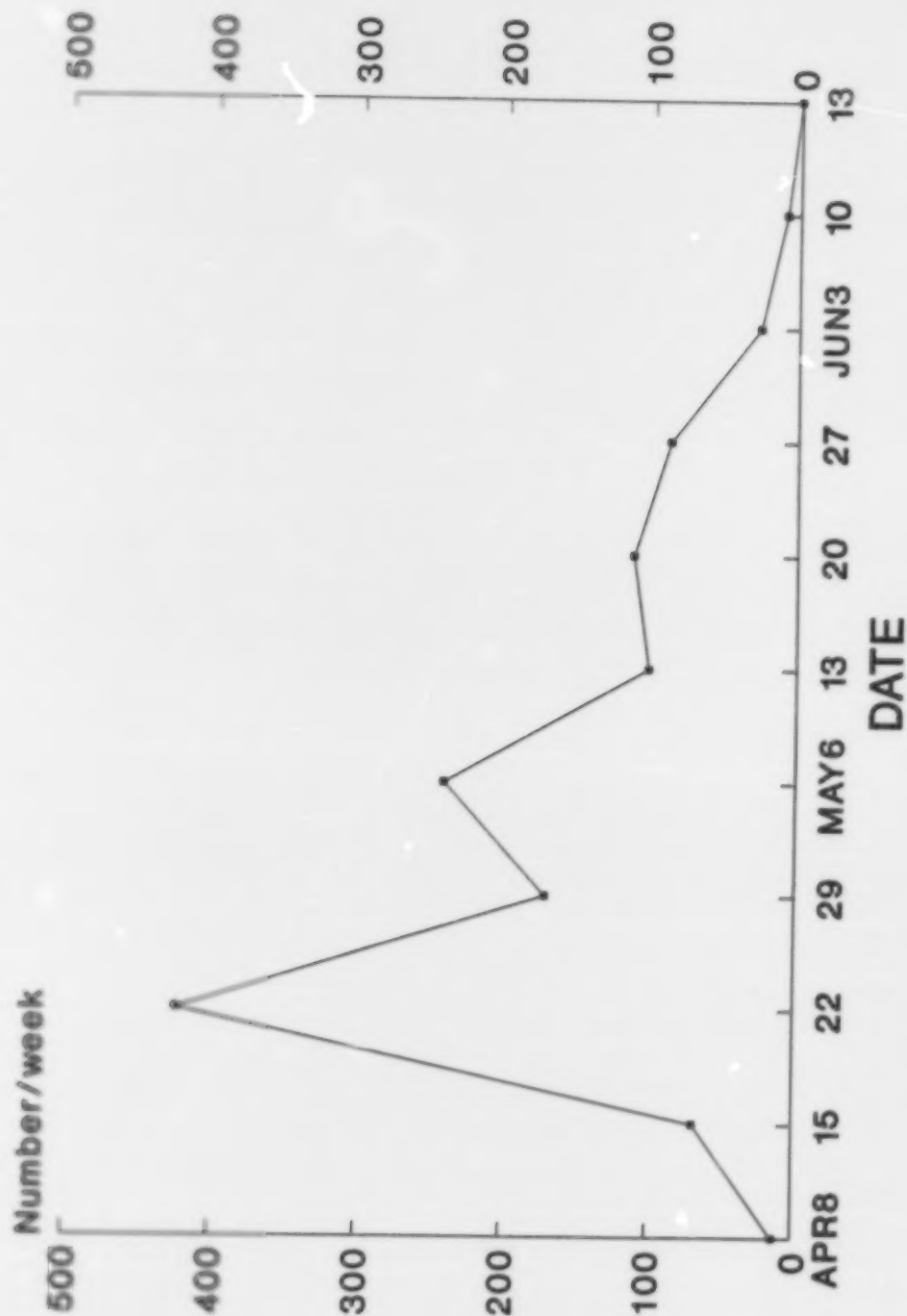


Figure 10. Pattern of the timing of the cottid migration downstream through the Keogh River fish fence in 1990.

Dolly Varden

The catch of Dolly Varden adults which migrated downstream in 1990 was 721 fish, an average run strength (Smith and Slaney 1980). Mean length and weight was 259 mm and 82.6 g, respectively (Table 3). Two migration peaks were observed: 113 and 107 fish on April 18 and May 1, respectively (Fig. 8).

The total catch of Dolly Varden smolts for 1990 was 3,200, also of average strength (Smith and Slaney 1980), with a mean length of 145 mm and a mean weight of 18.8 g (Table 3). A peak of 604 fish was observed May 7 (Fig. 8). The total parr catch for 1990 was only 50; these parr had a mean length of 110 mm and a mean weight of 3.5 g., similar to past years (Table 3).

Cutthroat Trout

Small numbers of cutthroat trout were enumerated at the Keogh River fence in 1990, as in past years. Only one kelt was captured, on May 27 (329 mm, 254.9 g). Other cutthroat classified as adults were fish lacking both the marks characteristic of parr and the silver coloration characteristic of smolts. The adult catch was 40, 75% of which were captured between May 3 and May 10 (Fig. 9). Mean adult length and weight was 172 mm and 53.4 g, respectively (Table 3). These fish classed as adults may in fact be stream resident fish. The smolt catch was 126; 52% of these were captured from June 1 to June 13 (Fig. 9). Mean smolt length was 160 mm and mean weight was 38.6 g (Table 3). The parr catch was 39 (Fig. 9), with a mean length of 127 mm and a mean weight of 20.6 g (Table 3). Because numbers of smolts and adults were consistently low, it is probable that a sea-run stock is subordinate to the resident stock in the watershed.

Cottids

Cottus asper and *C. aleuticus* were pooled during enumeration this year. The peak in cottid migration in 1990 occurred from April 18-19 when 110 and 113 fish were captured, respectively (Fig. 10). The total catch was 1388, with a mean length of 125 mm and mean weight of 30.7 g (Table 3).

CODED-WIRE TAGGING

Steelhead Smolts

A total of 1,423 steelhead smolts, or 45.4% of the smolt emigrants, were tagged with adipose cwts and released in 1990. Tagging did not begin until May 16, when tags became available. Mean processing time per fish decreased from 2.2 minutes to 1.5 minutes to 1.1 minutes for crews of 1, 2, and 3 people,

Table 4. Time required for one, two or three people to handle fish, inject tags and load syringes to coded-wire tag Keogh River steelhead smolts in the adipose fin during 1990 trapping.

Date	Number of fish	Time (hr)	Minutes/fish	Number of People
May 26	10	0.25	1.5	1
May 28	7	0.33	2.85	1
May 31	49	1.5	1.83	2
June 1	10	0.35	2.1	2
June 2	65	1.08	1.0	3
June 2	24	0.5	1.25	2
June 3	58	1.08	1.1	3
June 4	136	2.25	0.98	2
June 4	45	0.93	1.2	2
June 5	88	1.54	1.05	3

Mean injection time/fish = 12.8 sec. (S.D. = 8.16, n = 40).

Mean loading time/syringe = 22.7 sec. (S.D. = 4.04, n = 30).

Table 5. Retention of coded-wire tags placed in the adipose fin of Keogh River steelhead smolts after 24 and 72 hr.

Date	Test duration (hr)	n	Retention (%)	Inspection Method	Mortalities
May 16	24	24	100	QCD	0
May 25	72	16	100	QCD	0
May 29	24	20	100	Visual	0
May 30	24	20	95	Visual	0
May 31	24	24	92	Visual	0
June 1	24	29	97	Visual	0
June 5	24	100	100	Visual	1
Sum		233			1

Mean retention rate = 98%

Mean mortality rate = 0.4%

Table 6. Loss rate for coded-wire tags in nasal cartilage of coho salmon smolts at the Keogh River, 1990.

Sample Period	Tag Code	Number Tagged	Loss Rate (%)	Mean Length (mm)	Mean Weight (g)
May 1-12	02-08-37	9726	0.35	104	11.6
May 13-19	02-08-38	7311	0.74	101	10.3
May 20-31	02-27-10	5678	0.86	100	8.9

respectively (Table 4). Thus a tagging team of three people was most rapid and least stressful on the fish (although least efficient of man-hours). Mean loading and injection times were 22.8 s and 12.8 s, respectively (Table 4).

Mean tag retention rate was 97.7%, based on seven 24-hr retention tests over the tagging period (Table 5). A total of 232 tagged smolts were inspected visually or by the cwt quality control detector for retention. Visual inspections were as reliable as machine inspections, and did not require anaesthetization of the fish. Those fish that had lost their tags were not retagged. One 24-hr retention test was extended to 72 hr: 100% retention was observed. The retention tests also permitted an estimate of tagging mortality, which was 0.4% (Table 5).

We attempted to test the effects of the use of 2-phenoxy ethanol as a fish anaesthetic for steelhead smolts by examining their mortality after 24, 48, and 72 hr in fresh and saltwater tanks. The following results were obtained:

	no. fish	Mortality		
		24hr	48hr	72hr
saltwater anaesthetized	10	3	8	8
freshwater anaesthetized	10	0	0	0
saltwater non-anaesthetized	10	3	4	5
freshwater non-anaesthetized	10	1	1	1

Placement of smolts directly in salt water (28 ppt) had more of an impact on steelhead smolts than the use of 2-phenoxy ethanol anaesthetic alone. Anaesthetized fish placed in freshwater holding tanks (5 fish per tank, continuously oxygenated) showed zero mortality after 72 hr. Thirteen of twenty smolts held in salt water died, whereas only one (non-anaesthetized) died in fresh

water. Due to the small sample size, we could not detect a significant difference between anesthetized or non-anesthetized smolts placed in salt water. However, the data suggests that smolts do not enter salt water directly, but acclimatize to it gradually. This test needs to be repeated under more controlled conditions with larger numbers of fish under standardized conditions of acclimation.

Coho Smolts

A total of 22,715 wild coho smolts were coded-wire tagged and released during May, 1990 (Table 6) through cooperative efforts with scientists of the Pacific Biological Station (J. Irvine and R. Bailey). Tagging mortalities during this period were 172 (0.8 %), which has not been subtracted from either daily or grand totals for smolt trap captures in 1990. Another 138 smolts were sacrificed for inspection of the depth of tag insertion and were likewise included in smolt trap captures for 1990. Those smolts which had lost tags during the period of the retention tests (Table 6) were retagged and released.

If repeated, information gained from these tagged fish, as well as that from the tagged steelhead smolts, will aid in comprehension of the biology of salmonids and allow more detailed comparison of the optimal timing for wild and hatchery smolts (Irvine and Ward 1989). Likewise, it will require repeated tagging efforts to more fully understand other complex and variable salmonid life history characteristics which relate to survival and age at return, as previously noted (Ward and Slaney 1988, Ward et al. 1989). The results from research at the Keogh River during the spring of 1990 form a small but significant step along that path.

ACKNOWLEDGEMENTS

We especially thank Pat Slaney, who reviewed the draft and provided enthusiastic support for anadromous salmonid research at the Keogh River. Drs. Art Tautz and Dave Narver are acknowledged for their direction. We also thank Bob Land and staff, Kelly Wilcox and the staff of the Northern Vancouver Island Salmonid Enhancement Association, Caroline C. Melville, Jacques Arsenault, Forrest Stokstad, Dr. Jim Irvine, Richard Bailey, Jim Ferguson, Joel Sawada, Dr. Tom Northcote, Dr. Don McPhail, Gary Hass, Ray Logan, Frank Dalziel, and all others who contributed.

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